PhD Proposal 2017

School: Ecole Centrale de Lille	
Laboratory: CRIStAL ((Research center in Computer Science, Signal and Automatic Control of Lille)	Web site: http://www.cristal.univ-lille.fr/
Team: MOCIS	Head of the team: B.OuldBoumama
Supervisor: A.RAHMANI	Email: Email: ahmed.rahmani@ec-lille.fr qzhan@buaa.edu.cn
Collaboration with other partner during this PhD: In France:	**In China:** Qiang Zhan Laboratroy of Complex Mechanism and Intelligent Control Robotics Institute, Beijing University of Aseronautics and Astronautics Phone: 86-10-82317729 Fax: 86-10-82317729 Email: qzhan@buaa.edu.cn

Title: Dual Arm Control and manipulation of mobile robot
• **Scientific field: Information Technology – STIC : Mechatronics /Robotic /Transportation/Traffic control, Image processing, Artificial intelligence.**
Key words: Mobile manipulator, dexterous hand, dual arms control , interactio Human Robot •

Details for the subject:

In recent years, the study of service robots is currently a very active area in robotics. Service robots are semi or fully autonomous machines that can mimic humans with human-like motions. They can assist human beings, typically by performing a job that is dirty, dull, distant, dangerous or repetitive, including household chores such as cutting the lawn, cleaning, housekeeping, and more. Meanwhile, the development of service robots for health care and assistance to elderly, disabled, or impaired people is an active area of research.

Our current project pursues the prototype development of a service robot for assistance tasks in household environments. The robot can move in a domestic environment, performs the same tasks as a mobile robot in a dynamic environment with obstacles. The manipulator must have the same capabilities of object's manipulations as a human. The robot must be able to communicate and interact with other entities (human, and machines) through a suitable network.

This global project is a part of collaboration between A.Rahmani (Centrale Lille) and Q. Zhan (BUAA) in the LIA 2MCSI (2011-2014). During this period, the main results obtained by Y. Qian (CSC thesis 2010-2013), and Y Wei (CSC thesis 2014-2017) are summarized bellow.

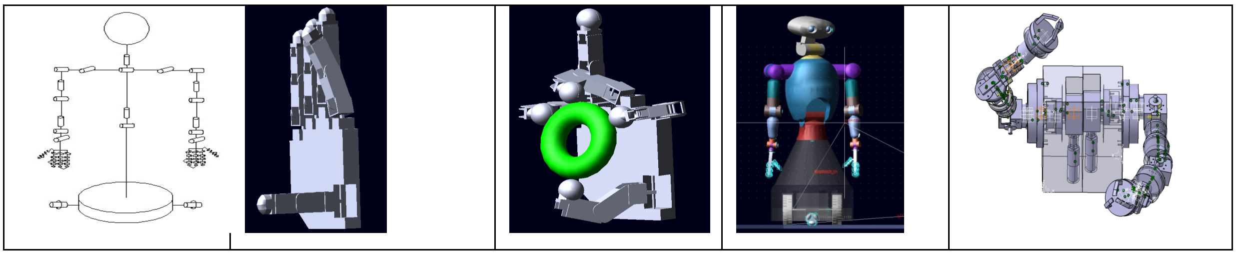
A Virtual Prototype was obtained**.** A 56 degrees of freedom (DOFs) robot is constructed with repeated several robotic chains for the trunk, arms and dexterous hands. The three-dimensional (3D) mechanical structure designed in SOLIDWORKS is exported to Automatic Dynamic Analysis of Mechanical Systems (ADAMS) software in order to perform motion simulations. The virtual prototype in ADAMS provides a tool to explore many issues involved in service robotics. Kinematic and dynamic simulations to the robotic system are made based on ADAMS.

To control the robot, a model is needed. The kinematic and dynamic models of the robot are developed. The kinematic model of the robot based on Modified Denavit-Hartenberg method is developed, and then the dynamic model is derived by the standard Euler-Lagrange formulation. As the mathematical model is frequently used for several different purposes there is a need for finding ways of facilitating connection of submodels to extend these models. A novel approach, bond graph approach, to model the robot is introduced. The overall bond graph model of the service robot is build step by step following the Newton-Euler formalism which has been widely used for modeling this kind of system. These two models are compared and validate using the virtual prototype.

Some algorithms that develop motion planning and control policies for the robot behaviors were proposed. First, a new algorithm to solve the motion-planning problem is introduced. Service robots operating in human-centered environments should be able to plan collision-free motions for grasping and manipulation tasks. Thus, the problem of collision-free path planning for a redundant manipulator with the given desired pose (position and orientation) is considered. For orientation, quaternion representation is applied to give singularity-free orientation control. A hybrid algorithm of combining the Jacobian pseudoinverse algorithm with Rapidly-Exploring Random Tree (RRT) method is presented. The nearest configuration point to the goal pose in task space is taken as the expanded node of the tree. The best expanding direction is calculated with the Jacobian pseudoinverse control algorithm. And the velocity of the end-effector of the manipulator is restricted by using the bisection gradient-decent extend algorithm to avoid the occurrence of joint velocity mutation. An intelligent robust controller based on neural network is introduced for coordinated control of a mobile manipulator. Unknown dynamic parameters of the mobile platform and the manipulator are identified and compensated in closed-loop control using Radial Basis Function (RBF) neural network. The output errors due to disturbances can be completely eliminated by this method. The weighting matrices, centers and widths of the RBF structure in the proposed method can be updated on-line.

For many tasks the mobile manipulator comes in contact with a constrained surface, and an interaction force develops between the end-effector and the environment. Therefore, the contact force control is at least as important as the position control. In such cases, the trajectory and the constraint force of the system are required to asymptotically converge to the desired ones, respectively. A similar control algorithm based on RBF neural network is presented for coordinated force/motion control of a mobile manipulator suffering both holonomic and nonholonomic constraints in the presence of uncertainties and disturbances.

Object manipulation with a multi-fingered mobile manipulator is a challenging task, especially in service robot applications. We proposed kinematics and dynamics of the dual-arm/hand mobile manipulator system manipulating an object with known shape by rolling contacts. A computed torque control algorithm is presented to ensure firm grip, avoid slippage and well track a given motion imposed to the object. All the results are validate using the virtual prototype.



Research subject, work plan:

The mobile robot has to share the same space than the helped person at home, so the robot must guarantee the human safety. The robot must avoid hurting human when he serves him or help him in some tasks. The robot must not cause any stress during the interaction. The robot must to interact with human, realize several tasks in parallel to manage various information coming from sensors, camera, and other connected objects. In this project, we will consider more sophisticated control laws allowing the robot to perform more complex tasks, including coordinating the movements of both arms simultaneously.

In this thesis will be discussed theoretical and practical aspects:

1) From a theoretical perspective, the following issues will be addressed:

- Interaction between the robot and the human. This will be done in several steps, beginning with the direct interaction then indirect interaction. During the indirect interaction the robot reacts to information from humans (voice commands or by remote control), sensors (position, fall, intrusions, ..) of cameras (detection of position, gesture, or monitoring). In the case of direct interaction, the robot must be able to react intelligently to the behavior of the human, its position, its movements, ...
- The robot must be able to perform several tasks of daily life and thus the simultaneous control of both arms and both hands is required. The control of arms is an open problem for robot manipulators and is even more so in the case of mobile manipulators. We begin by extending our previous results in both arms in simple cases of equivalent positions and to perform simple tasks, like carrying an object. Then, for more complex tasks, the simultaneous control of both arms and both hands will require new control laws.
- Path planing of mobile robot. The robot must navigate autonomously, avoiding static and moving obstacles, and share its space with humans. Path planning results must be improved to take into account in particular the movement of the human.

2) From a practical point of view:

The candidate will have to participate in the Lab Linving current project (model apartment equipped to accommodate the latest results in terms of assistance to a person with disabilities home).

It should especially test all the results on the platforms available.

References:

- Y. Qian, A. Rahmani, “Path Planning Approach for Redundant Manipulator Based on Jacobian Pseudoinverse-RRT Algorithm” Intelligent Robotics and Applications, Lecture Notes in Computer Science, Springler verlag , Part I , Volume 8102 2013, pp Pp 706-717, ISBN: 978-3-642-40851-9 (Print) 978-3-642-40852-6 (Online),
- Yang Qian and Ahmed Rahmani, "Rbf-Neural Network Adaptive Control Of Mobile Manipulator" Robotica, ID ROB-REG-13-0139. The reviewers have recommended for publication with some suggest revisions (29 octobre 2013), to be published in December 2014.
- Y. Qian, A. Rahmani, “Virtual Prototyping and Control of a Dexterous Hand” Proceedings of 2013 IEEE-RAS International Conference on Humanoid Robots, October 15 - 17, 2013, Atlanta, GA
- Y. Qian, A. Rahmani, “Bond graph modeling and simulation of a dexterous hand ”, INACoMM 2013, 18-20 December 2013, Roorkee , India.
- Y. Qian, A. Rahmani, “Bond Graph Modeling and Simulation of a Dual-Arm Mobile Manipulator ”, INACoMM 2013, 18-20 December 2013, Roorkee , India..
- Y. CAI , Q. Zhan & A. Rahmani ; Inverse Kinematics Identification of a Spherical Robot Based on BP Neural Networks, 6th IEEE Int Conf on Industrial Electronics and Applications Beijing, 21-23 June, 2011: 2114-2119.
- Y. Qiang, A. Rahmani & Q.Zhan « Bond graph modeling of a Mecanum wheeled robot » ICBGM 2012, 10th International Conference on Bond Graph Modeling And Simulation July 8-11, 2012 Genoa, Italy.
- Zhan Qiang, Hu Wei, Cai Yao. Design and Control of a Novel 1-DOF Robotic Hand. 2011 3rd IEEE International conference on Computer and Network Technology, Taiyuan, February 26-28, V3: 45~49.
- Qiang ZHAN, Rui YANG. Design and Optimization of a Robotic Finger [C]. The 6th IEEE Conference on Industrial Electroincs and Applications, Beijing, 21-23 June, 2011: 1128-1133.
- Caixia YAN, Qiang ZHAN. Real-time Multiple Mobile Robots Visual Detection System. Sensor Review, 2011, Vol. 31, Issue 3: 228 – 238